A fully adaptive nonintrusive reduced-order modelling approach for parametrized time-dependent problems

Fahad Alsayyari*, Zoltán Perkó, Marco Tiberga, Jan Leen Kloosterman, Danny Lathouwers

Delft University of Technology, Faculty of Applied Sciences, Department of Radiation Science and Technology, Mekelweg 15, Delft, 2629JB, The Netherlands

Received 16 March 2020; received in revised form 28 September 2020; accepted 2 October 2020

Available online xxxx

Abstract

We present an approach to build a reduced-order model for nonlinear, time-dependent, parametrized partial differential equations in a nonintrusive manner. The approach is based on combining proper orthogonal decomposition (POD) with a Smolyak hierarchical interpolation model for the POD coefficients. The sampling of the high-fidelity model to generate the snapshots is based on a locally adaptive sparse grid method. The novelty of the work is in the adaptive sampling of time, which is treated as an additional parameter. The goal is to have a robust and efficient sampling strategy that minimizes the risk of overlooking important dynamics of the system while disregarding snapshots at times when the dynamics are not contributing to the construction of the reduced model. The developed algorithm was tested on three numerical tests. The first was an advection problem parametrized with a five-dimensional space. The second was a lid-driven cavity test, and the last was a neutron diffusion problem in a subcritical nuclear reactor with 11 parameters. In all tests, the algorithm was able to detect and include more snapshots in important transient windows, which produced accurate and efficient representations of the high-fidelity models.

© 2020 The Author(s). Published by Elsevier B.V. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).

Keywords: Proper orthogonal decomposition; Data-driven; Greedy; Time-adaptive; Locally adaptive sparse grid

1. Introduction

In science and engineering applications, dynamic models can be described by time-dependent mathematical models. Often, these models are written as parametrized partial (integro-) differential equations (PDE). Applications such as uncertainty and sensitivity analysis and design optimization require solving the equations repeatedly for different values of the PDE parameters. For complex, large-scale problems, applications of repeated evaluations demand excessive computational power and memory resources. In such cases, model reduction techniques are used to overcome the computational burden. Model reduction methods aim to replace the high-fidelity model with an efficient, low-dimensional reduced-order model (ROM) capturing the main dynamics of the system with a controlled level of accuracy. Model reduction methods can be classified into intrusive and nonintrusive methods. Intrusive

* Corresponding author.
E-mail address: f.s.s.alsayyari@tudelft.nl (F. Alsayyari).

https://doi.org/10.1016/j.cma.2020.113483
0045-7825/© 2020 The Author(s). Published by Elsevier B.V. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).